16

$365.00 201 A

08/472876

TRD 001 IA

APPARATUS AND METHOD OF ENHANCING ELECTRONIC AUDIO SIGNALS

RELATED APPLICATIONS

This application is a continuation-in-part of the PCT application PCT/US94/12328, filed October 27, 1994, which is a continuation-in-part of the U.S. application Serial No. 08/021,209, filed February 23, 1993, now U.S. Patent No. 5,361,306.

FIELD OF THE INVENTION

The present invention relates to an apparatus and method for enhancing electronic audio signals in order to improve the quality of sound produced from those signals, and more particularly to an apparatus and method for adding enhancing harmonics to the electronic audio signal.

BACKGROUND OF THE INVENTION

Hearing music, singing or other such sounds live has often been considered more pleasurable than hearing the same sound after it has been converted into an electronic audio signal and re-converted back into audible sound. There can be many reasons for this perceived drop in quality. One reason resides in the sound reproduction process itself.

Many of the sounds we hear, especially musical notes, are often a composite. For example, a musical note having a basic pitch or fundamental frequency, usually contains components of the fundamental frequency called harmonics. These harmonics create the tonal quality or timbre of the sound, such as a musical note, that is often unique to the musical instrument or other sound producing source. In other words, these harmonics enrich the sound we hear. While the human ear typically cannot discern the individual harmonics, it can perceive the presence or absence of these harmonics as a respective increase or decrease in the quality of the sound. Devices for converting live sound into electronic audio signals (for example, microphones or similar devices) typically do

not adequately register and convert the full quality of the live sound. Thus, the electronic audio signals do not include many of the original harmonics. Numerous sound reproduction systems have been developed in an attempt to add harmonic enhancement to such deficient audio signals. However, these systems are often very sophisticated and expensive and the sound quality produced with such systems still falls short of the original quality of the sound heard live.

Another reason reproduced sound is often perceived to have a lower quality than live sound can be attributed to the environment in which the sound is produced and recorded. For example, music played in an open field typically sounds one dimensional because much of the sound waves dissipate into the field and are not heard by a listener. On the other hand, music played in an acoustically designed room usually sounds richer and fuller, and individual sound sources, for example, musical instruments, are typically more distinguishable. One reason for this difference is that the sound heard by the listener includes high quality reverberations which combine to produce audible sound with a greater high quality harmonic content.

Not all reproduced sound originates in an acoustically designed environment and therefore does not have the benefit of such high quality reverberations. Even when an acoustically designed environment is used, high quality reverberations can get lost in the recording process, for instance, if the sound converting equipment (for example, a microphone or the like) is unable to register them.

Another problem with reproduced sound, such as music, is that it can become distorted when heard at high volumes. It is often difficult to clearly hear the words being sung in a song or distinguish one musical instrument from another as the volume increases.

An additional problem is that the quality of recorded music being played in a room can vary depending upon the room geometry and upon where the listener is located in the room with

respect to the sound source (for example, speakers). When this occurs, the music sounds better at one or more specific locations in the room. Such locations are often referred to as sweet spots. Thus, in order to enjoy the full potential of the recorded music, a listener is forced to remain at these sweet spots.

Various sophisticated and expensive systems have been developed in an effort to produce an enhanced electronic audio signal which, when converted into audible sound, is perceived as more closely duplicating the experience of hearing the original live sound in an acoustically designed environment. The present invention is an improvement thereon which is relatively inexpensive and uncomplicated.

SUMMARY OF THE INVENTION

In accordance with the present invention, methods and apparatus are provided for simply and inexpensively enhancing an electronic audio signal in such a way that the quality of audible sound produced from the audio signal more closely approaches that of the original sound as if heard live in an acoustically designed environment. In this way, the ~~The~~ present invention adds enhancing harmonics to the electronic audio signal. Sound produced from an audio signal enhanced in accordance with the present invention appears to resist becoming distorted at high volumes and tends to eliminate, or at least significantly reduce, the formation of sweet spots.

Ins A1

a

To these ends, and in accordance with the principles of one aspect of the present invention, the electronic audio signal is transmitted through a magnetic coil audio energy transfer system which enhances the electronic audio signal in such a way that audible sound produced from the enhanced audio signal is perceptibly richer and fuller. More specifically, the electronic audio signal is electrically transmitted through an electromagnetic field inducing coil to generate a field signal correlated to the original electronic audio signal. The field signal is then weakly or loosely coupled to a field receptor which converts the field signal into an enhanced, but weak, electronic audio signal which can then

be amplified, if necessary, for reproduction on conventional audio reproducing equipment, such as speakers and the like. With weak or loose coupling, only a small portion of the electromagnetic field set up by the inducing coil cuts or passes through the field receptor. The weak coupling of the induced field signal to the receptor results in the electronic audio signal, and thus sound generated from the signal, being enhanced by the ~~addition~~ accentuation of desirable harmonics.

Weak or loose coupling between the inducing coil and the field receptor causes the well known negative signal distortion of the high frequencies being favored and low frequencies being attenuated. The present invention is predicated at least in part upon the discovery that ~~along with~~ this ~~type of~~ undesirable distortion or degradation ~~there is also~~ can impart a desirable distortion or enhancement ~~resulting from~~ the addition of desirable harmonics to the signal. It is believed that this potential for harmonic enhancement remained ~~undetected~~ unknown, until now, because ~~the~~ only harmonic enhancement from such a negative distortion (i.e., favoring of high frequencies at the expense of low frequencies) was ~~made such harmonic enhancement~~ unrecognizable. Because the ~~undesirable~~ distortion associated with weak coupling is so well established and well known as being undesirable and ~~the discovered~~ because the potential for harmonic enhancement was unknown, weak coupling has been avoided, not embraced, as in the above aspect of the present invention. The inducing coil and the field receptor of the present invention are weakly or loosely coupled in order to promote this undesirable distortion because of the previously unknown harmonic enhancement.

It is believed that the field inducing coil can be a wire winding with at least one turn, but it is desirable for the inducing coil to be a wire winding with a plurality of turns. It is believed that the receptor can be an electromagnetically conductive wire, plate, tube or other structure, but it is desirable for the field receptor to be a coil with a plurality of turns. It is desirable for the field inducing coil and the field receptor coil to have the same number of turns, and even more desirable for the field receptor coil to have more turns than the field inducing coil. The inducing and receptor coils can each be

mounted on a separate core or both mounted on a single shared core. The inducing and receptor coils can also be mounted end-to-end, side-to-side or one around and at least partially overlapping the other. It is desirable for the cores to be non-permeable or at least low permeable cores, for example, air, plastic and cardboard cores.

By virtue of the foregoing, there is thus provided a simple and inexpensive apparatus and method for enhancing an electronic audio signal so as to have a quality when aurally reproduced approaching that of original live sound as heard in an acoustically designed environment.

The objectives, features and advantages of the present invention will become further apparent upon consideration of the following description and the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block schematic diagram of an audio signal enhancing apparatus in accordance with the principles of the present invention;

Fig. 2 is a perspective view of one embodiment of an inducing coil and a field receptor coil according to the present invention;

Fig. 3 is a circuit diagram of a dual channel audio signal enhancing apparatus similar to the apparatus of Fig. 1;

Fig. 4 is a diagrammatic sectional side view of an alternative embodiment of an inducing coil and a field receptor coil according to the present invention; and

Figs. 5A and 5B together are a circuit diagram of an alternative dual channel audio signal enhancing apparatus, similar to the apparatus of Fig. 1, for use with the inducing coil and field receptor coil embodiment of Fig. 4.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Fig. 1, there is shown one embodiment of a system 10 for enhancing electronic audio signals according to the

principles of the present invention. System 10 includes an input stage 12 having power supply 14, input amplifier 16, and electromagnetic field inducing coil 18 through which multiple frequency input electronic audio signals are driven by amplifier 16 to generate a field signal correlated to the original input signal from a source 20 of electronic audio signals, such as a microphone, magnetic tape player, optical disc player, radio receiver, television audio receiver, telephone receiver or the like. System 10 also includes an output stage 22 for converting the generated field signals from input stage 12 into electronic audio signals which are enhanced according to the principles of the present invention and which can be reproduced into audible sound by conventional sound producing equipment 24, such as speakers and the like, or recorded onto a recording medium. Output stage 22 includes a field receptor 26 connected to output amplifier 28 which is powered by power supply 30. Field receptor 26 is positioned to receive very weak portions of the field signal created by coil 18 without inducing any appreciable amounts of undesirable feedback currents in coil 18.

Input amplifier 16 is a power amplifier which greatly amplifies and drives the input signal from source 20 through coil 18 of input stage 12 with sufficient strength to be received by receptor 26 for conversion into an enhanced electronic audio signal comprising the original input signal with accentuated ~~plus additional~~ desirable harmonics. The field signal thus induced at coil 18 is weakly coupled to field receptor 26 of output stage 22. That is, the receptor 26 is placed within the field created by coil 18 but at a sufficient distance electromagnetically so as to receive the enhanced signals without introducing undesirable feedback in coil 18. Weakly coupled coil 18 and receptor 26 form a magnetic coil audio energy transfer system 54.

It is believed that coil 18 can be a single-turn coil of insulated wire 34 wound on a core 36 and that receptor 26 can be a conductive wire, tube or plate. However, it is desirable for both coil 18 and receptor 26 to be a multiple-turn coil of insulated

magnetic wire 34 and wire 44, respectively, with the same number of turns. While coils 18 and 26 are shown as being cylindrical or circular in shape, the present invention is not intended to be so limited. Receptor coil 26 is wound on a core 46 which desirably forms part of the same core as core 36. In response to the field signal from coil 18, the enhanced electronic audio signal is generated in the receptor coil 26 but, because of the weak coupling, at a very low amplitude compared to the input signal driven through coil 18. The enhanced signal is so weak as it passes through receptor coil 26 that any field signal the enhanced signal induces is too weak to generate a significant feedback signal of its own in coil 18. The output of coil 26 is connected to output amplifier 28 in order to amplify the enhanced signal enough to be used by the sound reproduction equipment 24.

It will be appreciated that the field signal induced by coil 18 is weaker for lower frequencies than for higher frequencies. Therefore, the lower frequencies of the enhanced audio signal generated by receptor coil 26 are weaker than its higher frequency components. In other words, before it is amplified, the high frequency end of the enhanced audio signal has a higher amplitude ~~(power level)~~ than its low frequency end as compared to the original input audio signal driven through coil 18. B3 It is ~~therefore~~ desirable for the output amplifier 28 to ~~include a~~ the amplification of frequency shaping network ~~109~~ B9 (see Fig. 3) which ~~favors~~ B5 the low frequencies ~~and attenuates the high frequencies so that the net~~ result is a fairly flat frequency response when comparing the input audio signal before it enters input stage 12 and the enhanced audio signal as it leaves output stage 22.

B Ins B3

B Ins B4

B B3

As seen in Fig. 2, it is desirable for cores 36 and 46 to each form part of a single core member 52 such that coils 18 and 26 are coaxial along central axis 48 and spaced apart by a distance G. Although shown as a tube of cardboard, plastic or other suitable material with a circular cross-section, core 52 could have other cross-sections, such as rectangular, and could be a solid bar of acrylic or other sufficiently low permeability material. By being

wound on a single core 52, it can be seen that coils 18 and 26 of energy transfer system 54 appear as the primary and secondary, respectively, of a lossy transformer. That is, the coupling between the coils 18 and 26 is deliberately weak so that there is little, if any, actual transformer action between the coils. Rather, coil 26 is believed to act primarily as a receptor of the field induced by coil 18 and is thus positioned relative to coil 18 so as not to significantly distort the enhancement of the input signal. The use of low permeability cores is desired and contributes to the weak coupling between the coils as is advantageous in the present invention. Also, by using one or more low permeability cores, such as with a permeability of approximately 1 or unity, the coils 18 and 26 can be kept close enough together to enable the input and output stages 12 and 22 to be housed in a relatively small package. Use of higher permeability cores, and perhaps even a ferromagnetic core, may suffice although the spacing between the coils will likely become large to maintain the weak coupling. Additionally, other than a coil, it is believed that receptor 26 could instead be a magnetically conductive plate, length of wire, tube or other structure which will receive and convert the field induced by coil 18 to a new and enhanced electronic audio signal.

To enhance the operation of system 10, it is desired that the input stage 12 and output stage 22 be well isolated, electrically and electromagnetically (except for the weak field coupling through system 54, at the interface of coils 18 and 26). To this end, separate power supplies 14 and 30 are provided in the respective stages 12 and 22, each with a separate ground. Also, each of the power supplies 14, 30 is kept physically remote from both stages 12, 22 or shielded from stages 12, 22 such as with shielding techniques and materials well known in the art.

A conventional audio signal source 20 (such as a microphone, magnetic tape player, optical disc player, radio receiver, television audio receiver, telephone receiver or the like) is usually connected to a sound producing device 24, such as

a speaker. When the device 24 converts the electronic audio signal from conventional source 20 into audible sound, the sound produced does not have the degree of richness and fullness (the quality) that the original live sound possessed before being recorded. The quality of the audio sound produced is substantially enhanced by the introduction of the present inventive system 10 between the source 20 and the device 24. The electronic audio signal output from signal source 20 is connected to the input stage 12 and the output of output stage 22 is connected to the input of sound converting device 24 so that any electronic audio signal must pass through the magnetic coil audio energy transfer system 54 before being converted into audible sound. When this audible sound is heard by a listener, its quality is enhanced to the point of sounding as if the original performance were being played live and in an acoustically superior environment. Preferably, two systems 10 (i.e., dual channels) are used, one for each respective channel of a stereo sound reproduction system.

One dual channel version of system 10 was built with the following commercially available electronic components:

(a) Dual Channel Input Amplifier (16) - Realistic S-20 solid state stereo 12 watt amplifier, Model No. 31-B;

(b) Two Input Coils (18) - Each a standard speaker coil, rated at 8 ohms and 2 watts;

(c) Two Receptor Coils (26) - Each a standard speaker coil, rated at 8 ohms and 2 watts; and

(d) Dual Channel Output Amplifier (28) - Realistic stereo 1.5 watt pre-amplifier, Model No. 42-2109.

The above speaker coils 18, 26 were taken from 3 inch diameter speakers manufactured by the Tandy Corporation, Model No. 40-248. Each winding 18, 26 had a width W (see Fig. 2) of about .15 inches (.38 cm), an inside diameter of approximately .52 inches (1.32 cm), and was formed by two layers of about 30 turns (about 60 turns total) of magnet wire having a length of approximately 105 inches (267 cm) and a diameter of about .005 inches (.013 cm), including its insulation. Each pair of windings 18, 26 were

mounted coaxially on a single core ~~50~~ 52 of solid acrylic having a rectangular cross section of approximately 3/4 by 1/4 of an inch (1.9 x .64 cm) and passing completely through both coils 18, 26. The gap G between the coils 18, 26 was on the order of approximately .060 inches (.152 cm). The Realistic amplifiers were also manufactured by the Tandy Corporation. Generally, the degree of amplification of the audio signal provided by the input amplifier 16 and the optimum gap G between the windings 18, 26 (see Fig. 2) are directly related. For example, with all other variables remaining the same, as the amplification of the audio signal by the input amplifier 16 increases, it is believed that the gap G will eventually need to be increased. As previously noted, the gap G is believed to also vary directly with the permeability of the core 52. This early embodiment of the present invention produced enhanced sound but also exhibited some undesirable characteristics. To overcome these problems, another dual channel embodiment of system 10 was built as now will be described with reference to Fig. 3.

Turning now to Fig. 3, there is shown a detailed schematic illustration of a dual channel or stereo version 100 of system 10 including a left side system 10a and an identical right side system 10b. Systems 10a and 10b share common input stage power supply 14 and common output stage power supply 30 as will be described. The input and output stages 12a, 12b and 22a, 22b of the two systems 10a, 10b are identical and therefore only the circuitry of system 10a will be described in any detail, it being understood that system 10b is the same.

More specifically, input stage 12a includes a first pair of electronic audio inputs 70, 72 connected respectively to the ground (GND1) of power supply 14 and of input stage 12a, and to 10 Kohm potentiometer 74. The wiper of potentiometer 74 is connected via 10 μF capacitor 76 to the non-inverting input of an LM383 operational amplifier 78. The output 80 of amplifier 78 is fed back to its inverting input from the junction of 1/2 watt grounded series resistors 84, 85 (200 ohm and 10 ohm, respectively), through

470μF capacitor 86. Output 80 of amplifier 78 is further connected to GND1 via the series branch of 1 ohm, 1/2 watt resistor 88 and .2 μF capacitor 90. Output 80 is next connected to the inducing coil 18 of magnetic coil audio energy transfer system 54 through 2,200 μF capacitor 92 to drive the electronic audio signal from inputs 70, 72 through coil 18 and induce the field signal as previously described.

Energy transfer system 54 includes field receptor 26 which is connected to a 1 Kohm potentiometer 96, the wiper of which is connected through 10 Kohm resistor 98 and 1 μF capacitor 101 to the non-inverting input of a LM1458N operational amplifier 102. The coil 18 and receptor 26 are each the same standard 8 ohm, 2 watt speaker coil found in the previously described version of system 10 using commercially available electronic components. Energy transfer system 54, both coil 18 and receptor 26, were fully encapsulated with a low permeability polymeric potting material for structural integrity. DP-270, a black epoxy potting compound/adhesive manufactured by 3M, St. Paul, Minnesota, provided sufficient structural strength and low permeability. Both coils 18 and 26 are potted in their original cylindrical configuration and in the coaxial orientation shown in Fig. 2, with a gap G of approximately .025 inches (.0635 cm). Output 104 of amplifier 102 is connected to enhanced audio output port 106 which, in cooperation with grounded output port 108, provides the enhanced electronic audio signal to reproducing equipment 24 as previously described. The junction of resistor 98 and capacitor 101 is connected to the output stage power supply ground (GND2) through a shaping circuit 109 comprised of three parallel circuit branches as follows: the series circuit of 5.1 Kohm resistor 110, .05 μF capacitor 111, and open ended 50 Kohm potentiometer 112; .002 μF capacitor 114; and the series circuit of 5.1 Kohm resistor 116 and .1 μF capacitor 117.

The output 104 of amplifier 102 is connected back to its inverting input via the series circuit of: parallel 499 Kohm resistor 122 and .005 μF capacitor 123; parallel 49.9 Kohm resistor

124 and .01 μF capacitor 125; parallel 10.0 Kohm resistor 126 and .005 μF capacitor 127; and 10.0 Kohm resistor 128. The inverting input of output amplifier 102 (as well as the inverting input of the comparable output amplifier in system 10b) is connected to a regulated voltage from regulator 129 of power supply 30 via 1.5 Kohm resistor 130 to the junction of 510 ohm resistor 132 and 5 volt zener diode 134 and 10 μF capacitor 136 which, at node 137, is at 5 volts. The non-inverting input of output amplifier 102 is similarly coupled to the 5 volt reference 137 via 100 Kohm resistor 138.

With respect to the power supplies 14 and 30, a dual transformer 140 provides about 14 volts to the balance of each supply 14 and 30, as will now be described. Input stage power supply 14 includes a diode bridge 142 which produces a full-wave rectified output from one 14 volt output of dual transformer 140. The full-wave rectified output is smoothed (filtered) by the circuit comprised of 1 ohm, 1/2 watt resistor 144, 2200 μF capacitor 145, 10 Kohm, 1/2 watt resistor 146 and 1 μF capacitor 147 to provide a nominal 18 volt unregulated supply and ground (GND1) for each of the input stages 12a and 12b. Similarly, the output stage power supply 30 includes a full-wave rectifier diode bridge 150 connected to the other 14 volt output of dual transformer 140. The output of bridge 150 is smoothed by the circuit comprised of 100 ohm, 1/2 watt resistor 151, 470 μF capacitor 152, 10 Kohm, 1/2 watt resistor 153 and 1 μF capacitor 154 to provide a nominal unregulated 18 volts to voltage regulator 129. The output of the voltage regulator 129 is bypassed to ground (GND2) via 10 μF smoothing capacitor 158 and .01 μF smoothing capacitor 160 and provides a regulated 12 volt supply and ground (GND2) for each of the output stages 22a and 22b. Capacitor 158 provides filtering for lower frequencies and capacitor 160 provides filtering for higher frequencies. Note that the input amplifiers 78 of each system 10a and 10b have been provided in separate integrated circuit packages and independently powered from supply 14 whereas output amplifiers 102 of each output stage 22a and 22b

have been provided in a single integrated circuit package and powered in common from power supply 30.

To prevent interference with the respective audio signals, it is desirable for that portion of power supplies 14, 30 before respective capacitors 147 and 154 to be kept remote from the input and output stages or, as previously discussed, shielded. In addition, the energy transfer system 54 (field inducing coil and field receptor) for each channel can also need to be shielded to protect system 54 from any unwanted interference external or otherwise.

In operation, the electronic audio signal for each channel is connected, by a standard jack or the like (not shown), to the respective input ports 70, 72. As will be appreciated, the electronic audio signal will normally include a wide range of audio frequencies. The respective input levels are adjusted at potentiometers 74 so that the input signal levels of the two channels are about equal and to allow input amplifiers 78 to amplify the input signals to the maximum extent possible without clipping or otherwise adversely distorting the input signals. Each ~~The~~ audio signal is ~~are~~ then enhanced through an energy transfer system 54 ~~and the enhanced signals adjusted in level by respective~~ B6 potentiometers 96 B7 ~~and for the desired flat frequency response by respective~~ potentiometers 112 ~~which~~ can ~~also~~ be used to alter the correspondin B8 shaping network~~s~~ 109 somewhat to adjust the tonal quality as desired for the listener. Each of the ~~The~~ B9 enhanced audio signal is ~~are~~ then amplified by an amplifier 102 and B10 connected through a set of the outputs 106 and 108 (such as by a standard jack) to sound reproduction equipment 24, such as another amplifier or speaker system, and is converted into audible sound. Alternatively, equipment 24 can be another recorder of electronic audio signals for recording the enhanced audio signals onto some form of recording medium, for example, magnetic tape or optical disk.

B B Ins B6 Ins B7 Ins B8 B Ins B9 Ins B10

Referring to Fig. 4, an alternative magnetic coil audio energy transfer system 50 has been found more desirable than system 54. Broadly speaking, alternative system 50 is formed with a

receptor coil 27 having a greater number of turns than its inducing coil 19. The receptor coil 27 is wrapped around a cylindrical core 53 made according to the principles of the present invention. For example, core 53 could be solid, made with a low permeability plastic material, such as nylon, and have a shoulder flange 55 at one end. Core 53 could also be an air core formed with or without a tube (similar to core 52) of cardboard, plastic or other suitable material. Alternatively, by using self-adhering magnet wire to form coils 19 and 27, the coils themselves can form the air core. The inducing coil 19 is wrapped around the outside of the receptor coil 27, in a mostly overlapping manner. Each coil 19 and 27 has an input and output lead 21a, 29a and 21b, 29b, respectively, with each lead passing through a hole formed through flange 55. Each of the leads 21a, 29a and 21b, 29b are adapted for being connected into an appropriate circuit, such as that described below and shown in Figs 5A and 5B.

By increasing the number of turns in the receptor coil 27 compared to the inducing coil 19, an electronic audio signal driven through the inducing coil 19 does not have to be amplified as much in order to induce a signal of sufficient strength in the receptor coil 27. In addition, it has been discovered that by altering the turns ratio in this manner, enhancement of the background noise in the original input signal can be reduced, without significantly affecting the enhancement of desirable portions of the original input signal.

Acceptable results have been obtained using various coil 27 to coil 19 turns ratios, including up to about 20:1. It is believed that even higher turns ratios can produce acceptable results. It has been found desirable to use an audio energy transfer system 50 exhibiting a coil 27 to coil 19 turns ratio of about 17.5:1 in the circuit shown in Figs. 5A and 5B and described below. In particular, this audio energy transfer system 50 has an output coil 27 formed with about 7,888 turns (i.e., 16 layers of about 493 turns/layer) of #48 AWG magnet wire and an input coil 19 formed with about 450 turns (i.e., 2 layers of about 225

turns/layer) of #41 AWG magnet wire. The output coil 27 has an inside diameter D_I of about 0.573 inches and both coils 19 and 27 have a winding width W_W of about 0.765 inches.

Turning now to Figs. 5A and 5B, there is shown a detailed schematic illustration of an alternative dual channel or stereo version 200 of system 10 including a left side system 162a and an identical right side system 162b. The systems 162a and 162b each have an input and output stage 163a, 163b and 164a, 164b, respectively. The input and output stages 163a, 163b and 164a, 164b of the two systems 162a, 162b share a common on-board D.C. power supply circuit 168, as will be described, and are identical. Therefore, only the circuitry of system 162a will be described in detail, it being understood that system 162b is the same.

More specifically, from a system input 169, an audio signal is transmitted through a 0.47 μF capacitor 170, which provides capacitive coupling (i.e., there is no DC component), to an LM358N buffer amplifier 171, having a gain of 1, which is used to separate the balance of system 162a from the source 24 of electronic audio signals being used. The signal coming out of amplifier 171 is transmitted through a 10.0 Kohm, 1% resistor 173 to another LM358N operational amplifier 174, which further amplifies and modifies the audio signal. The output of amplifier 174 is fed back to its input through three parallel circuit branches as follows: a 110 Kohm, 1% resistor 178; a .001 μF capacitor 179; and the series circuit of a 7.5 Kohm, 1% resistor 180 and a .047 μF capacitor 181. The resistor 173 and the resistor 178 determine the DC gain of the amplifier 174. The capacitor 179, resistor 180 and capacitor 181 perform a preshaping of the associated frequency response to somewhat attenuate the high frequencies of the audio signal and thereby minimize the high frequency response of the circuit.

The signal coming out of the amplifier 174 is fed into two opposing LM358N operational amplifiers, amplifier 182 and amplifier 183, forming part of the left-hand side and the right-hand side, respectively, of a bridge amplifier circuit 184. The

bridge amplifier circuit 184 is symmetrically centered around the magnetic coil audio energy transfer system 50 (see Fig. 4). With the amplifiers 182 and 183 operating in opposite directions, the same amount of power supply can provide twice the signal going into the system 50. In addition, by using the bridge amplifier circuit 184, the system 50 can be totally isolated from ground without using separate grounds for the input and output stage of each system 162a and 162b, as is the case with the systems 10a and 10b of Fig. 3.

The signal from the amplifier 174 is driven in series through a 24.9 Kohm, 1% resistor 188 and an LM358N operational amplifier 189 before being fed into the left-hand side of the bridge amplifier circuit 184 and amplifier 182. The output of amplifier 189 is fed back to its input through a 24.9 Kohm, 1% resistor 190. The resistors 188 and 190 are selected so that the amplifier 189 has a gain of 1. The amplifier 189 is connected to invert the signal. That is, there is a 180° phase inversion in the amplifier 189. The amplifier 174 also drives its output signal into the right-hand side of the bridge amplifier circuit 184 and the amplifier 183, but without an intermediate inverting amplifier. Thus, a differential signal is provided because the amplifier 174 drives the amplifier 182 through the inverting amplifier 189. In other words, while the amplifier 183 sees the signal going up, the amplifier 182 sees the signal going down. Other than this difference, the amplifiers 182 and 183 as well as the remaining components of the left-hand and right-hand side of the bridge amplifier circuit 184 are identical. Accordingly, only the left-hand side of the bridge amplifier circuit 184 will be described in detail below, with the corresponding components on each side, except for the amplifiers 182 and 183, being indicated using the same reference numbers.

On the left-hand side of the bridge amplifier circuit 184, the signal is driven into the amplifier 182 through a 24.9 Kohm, 1% resistor 191. The output of the amplifier 182 is connected to the 12 volt power supply of the circuit 168, indicated

by reference point 192 and described in detail below, through a series connection of a 100 ohm resistor 193, a 1N4148 diode 194 and a 10 Kohm resistor 198. The output of the amplifier 182 is also connected to ground through another series connection of a 100 ohm resistors 201, a 1N4148 diode 202 and a 10 Kohm resistor 203. These two series connections form a biasing network to drive a 2N3904 transistor 204 and a 2N3906 transistor 208, respectively. Transistors 204 and 208 form a complementary pair that effectively turn amplifier 182 into a power amplifier, not one that is very powerful but one more powerful than the operational amplifier 182 alone.

The signals from the transistors 204 and 208 are then used to drive the input 21a of the inducing coil 19 of energy transfer system 50. The signals from the transistors 204 and 208 pass through 10 ohm resistors 209 and 210, before entering coil 19. The resistors 209 and 210 are used for current limiting, to help stabilize the biasing of the transistors 204 and 210. At node 211, between resistor 209 and coil input 21a, the output of the amplifier 182 is fed back to its input through a 24.9 Kohm, 1% resistor 212. Resistors 191 and 212 are selected so that the amplifier 182 has a gain of 1. So, amplifier 182 and all of the surrounding components of the left-hand side of the circuit 184 effectively form a power amplifier with a gain of 1.

Generally speaking, on the left-hand side of the bridge amplifier circuit 184, the output of the amplifier 174 drives the amplifier 182, via the amplifier 189, and with a gain of 1, the amplifier 182 impresses its signal through the inducing coil 19, of the energy transfer system 50, to its lead 21b and the 5 volt reference power supply of circuit 168, indicated by reference point 213 and described in detail below. The 5 volt reference power supply 213 of circuit 168 effectively functions as a signal ground. In this way, coil 19 induces a field signal (see previous description). On the right-hand side of the bridge amplifier circuit 184, the output of the amplifier 174 drives the amplifier 183, and with a gain of 1, the amplifier 183 drives the signal

induced in receptor the coil 27, by the field signal from the inducing coil 19, through the coil 27, to its lead 29b.

The induced signal is driven from the lead 29b of the coil 27 through a 75.0 Kohm, 1% resistor 214 and into an LM358N operational amplifier 218. The output of the amplifier 218 is fed back to its input through four parallel circuit branches as follows: a 499 Kohm, 1% resistor 219; a 250 pF capacitor 220; the series circuit of a .001 μF capacitor 221 and a 100 Kohm, 1% resistor 222; and the series circuit of a grounded 10 Kohm variable resistor or potentiometer 223, a 10 Kohm resistor 224 and a 250 pF capacitor 228. The gain of the amplifier 218 is set by the resistors 219 and 214. In addition, the capacitor 220 in conjunction with the capacitor 221 and the resistor 222 are part of a frequency shaping network that determine the frequency response of the output amplifier 218. Furthermore, the potentiometer 223, the resistor 224 and the capacitor 228 form an additional frequency shaping network which is selectable via the variable resistance of potentiometer 223. That is, the potentiometer 223 allows the enhancement of the audio signal to be somewhat controlled by allowing the degree to which the audio signal is enhanced to be varied before reaching the system output 229.

The signal from the amplifier 218 is driven through a 10 Kohm variable resistor or potentiometer 230 to an LM358N operational the amplifier 231. The amplifier 231 is used to buffer or isolate the amplifier 218 from whatever sound processing equipment 24 is connected to the output 229. The potentiometer 230 is connected to the 5 volt reference voltage 213 of the power supply circuit 168 through a 5.1 Kohm resistor 232. The resistor 232 and the potentiometer 230 are used to set or trim the output level of the enhanced signal so that it conforms to the level of the input signal, as desired. In other words, the potentiometer 230 and the resistor 232 enable the amplitude of the enhanced output signal to be varied so as to at least approach, if not equal, the amplitude of the input signal.

The signal from the amplifier 231 is driven through a

0.47 μF capacitor 233 to the output 229. The capacitor 233 is used for DC blocking. The capacitor 233 is provided with a resistance back to ground, via a 100 Kohm resistor 234. A switch 238 is used to control whether the audio signal is to be enhanced (i.e., routed from the input 169, through the system 162a to the output 229) or transmitted directly from the input 169 to the output 229 and then to the conventional sound producing equipment 24, such as speakers and the like, or recorded onto a recording medium for ultimate reproduction into audible sound.

The input and output stages 163a, 163b and 164a, 164b of the two systems (channels) 162a and 162b share the common on-board power supply circuit 168 (i.e., the power supply circuit 168 is not remote from the systems 162a and 162b). The power supply circuit 168 regulates 18 volts which is supplied to its input 239 from an external power source (not shown). This 18 volts is filtered through a 2000 μF input filter capacitor 240. The filtered 18 volts passes through an LM317TB programmable voltage regulator 241 connected in parallel with a 240 ohm resistor 242 and grounded through a 2.7 Kohm resistor 243. Resistors 242 and 243 make up a divider that programs the voltage regulator 241 to produce a 12 volt output from the filtered 18 volts supplied by the input 239. The regulated 12 volts is then filtered through a 2000 μF output filter capacitor 244. At this point, the power supply circuit 168 separates into two branches.

Along one branch, the filtered 12 volts passes through a voltage regulator 248 and is filtered by a 470 μF filter capacitor 249 to produce a filtered 5 volt output. This filtered 5 volts forms a biasing reference voltage which sets an operating level for the amplifiers of each system 162a and 162b. It is believed that the actual value for this reference voltage is not critical. Whether the reference voltage is 5½, 6, 6½ or 7 volts, each system 162a and 162b should still function. The voltage regulator 248, with its 5 volt reference voltage, was chosen because it was readily available. Between each amplifier 171, 174, 189, 182, 183, 218 and 231 and the 5 volt reference voltage is a bias compensation

resistor 172, 250, 251, 252, 253, 254 and 232 of 100 Kohm, 10 Kohm, 12 Kohm, 24.9 Kohm (1%), 24.9 Kohm (1%), 10 Kohm and 5.1 Kohm value, respectively. The resistors 250, 251, 252, 253 and 254 each perform the same function of enhancing temperature stability but they are not essential to the operation of the systems 162a and 162b.

Along the other branch of power supply 168, the filtered 12 volts is further filtered through a 100 ohm resistor 258, a 470 μF filter capacitor 259 and a series of four .01 μF CD capacitors 260, 261, 262 and 263. The capacitors 259-263 filter noise that is in the line to condition or clean up the 12 volts of power supplied to the amplifiers of each system 162a and 162b. As would be understood by one skilled in the art, the power supply circuit 168 can be readily modified so that the 12 and 5 volts are separately provided while still achieving the same result. The separate 12 and 5 volt power supplies could also be replaced with a positive and negative voltage and the voltage regulator 241 and 248 eliminated (i.e., moved to the external 18 volt power source).

While the present invention has been described and illustrated with reference to a number of embodiments, and while these embodiments have been described in considerable detail, there is no intention to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. For instance, if the music or vocals from a compact disc player, in the form of electronic audio signals, is transmitted through an enhancing system according to the principles of the present invention and the resulting enhanced electronic audio signal re-recorded onto a cassette tape using a cassette player/recorder, the quality of the music or vocals produced from the recorded cassette tape has been found to be perceptibly better than the same music or vocals produced directly from the compact disc. This occurs even though the compact disc format is widely recognized as producing superior sound quality compared to the cassette tape format. It is believed that the present invention can be used to

enhance electronic audio signals from sound converting equipment, for example a microphone or the like, before being either recorded onto a recording medium (for example, magnetic tape or optical disk), transmitted through the air (for example, for a television or cellular telephone) or converted directly into audible sound (for example, through speakers at a concert, movie or play).

The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and method, and illustrative examples shown and described. Accordingly, departures can be made from such details without departing from the spirit or scope of the general inventive concept of the present invention.

What is claimed is: